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PERMANENT BENCHMARKS IN PERMAFROZEN FINE-GRAINED SOILS

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ARCTIC CONSTRUCTION AND FROST EFFECTS LABORATORY
U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
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PERMANENT BENCHMARKS
IN
PERMAFROZEN FINE-GRAINED SOILS

1. Introduction.

The problem of satisfactory benchmarks is common to all agencies doing engineering or investigational work in Alaska and other permafrost areas. This report presents a brief review of past experience and behavior of known benchmark installations in permafrost, together with the best recommendations for benchmark installations presently known. The Arctic Construction and Frost Effects Laboratory through its field office, the Fairbanks Permafrost Research Area, at Fairbanks, Alaska, has made a series of studies in the past, which it is planned to continue to determine the minimum effort and cost required for satisfactory benchmarks in all permafrost areas.

2. Past Experience of U.S. Coast and Geodetic Survey.

During the years 1945 to 1953, the U.S. Coast and Geodetic Survey made a stability investigation on a system of marked triangulation stations in permafrozen soils in the vicinity of Point Barrow, Alaska.* The active zone over the permafrost was not over about 1-1/2 feet thick. As shown on Figure 1, the benchmarks used were 2-inch I.D. brass or galvanized iron pipe, 5 or 6 feet long,

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* Jarman, J.T., Commander, Movement of Triangulation Marks Set in Permafrost, the Journal, Coast and Geodetic Survey, No. 6, pp. 11 - 22, Aug. 1955.

in which several small holes are drilled to permit escape of water. (A 3-foot length of pipe was used in 1945, but experience indicated this length too short). These monuments, similar to those used by the Russians in Siberia, were placed in steamed holes made in the permafrost using a small portable prospector's boiler. No protection from heave was provided.

Both horizontal and vertical movement difference observations were conducted for periods of from one to five years among 41 triangulation stations. The horizontal movement was quite small, the average being about 0.04 foot and some of this may have been measurement error. The upward vertical movements due to frost heave were greater than the horizontal movements and the results revealed that 36.0 percent of the measured vertical differences exceeded 0.02 foot, with an average movement of 0.091 foot. (It was arbitrarily considered by the author that a 0.02 foot vertical limit of error could be ignored in this analysis). The remaining 64.0 percent of benchmarks experienced an average upward vertical movement of 0.007 foot. These stations placed in dry, well-drained tundra, or in sand or gravel, were in general relatively stable. It was felt, however, that the period of observations was too short to reach definite conclusions except for indications or trends, and repeated observations at 5-year intervals would be required to get the final answer. Indications were that the movement of marks set in permafrost would not prevent their use in establishing

horizontal control of usual accuracy since the horizontal displacement is quite small. The amount of vertical movement was considered excessive for establishment of accurate vertical control. It was recommended that the Russian-type benchmark (Figure 2) should prevent or minimize movement in permafrost areas.

3. Experience at Fairbanks Permafrost Research Area, Corps of Engineers, U.S. Army.

In arctic areas with a relatively thick active layer and deep annual frost penetration, as at the Fairbanks Permafrost Research Area in Alaska, particular attention must be given to the effects of frost heave in the design of stable benchmarks. The criterion of only adequate depth into permafrost is insufficient, as pipe piles at the Research Area have shown upward vertical movement with an embedment into permafrost equal to two, three or more times the depth of the active zone. To investigate the stability of benchmarks subject to frost heave, five identical "non-heaving" benchmarks, as shown on Figure 3, were constructed at the Research Area in 1945 and 1946 (See Figure 4). The benchmarks were 2-inch diameter steel pipes, 32 feet long, placed in drilled holes and slurried up to a level 2 to 4 feet below the permafrost table or 10 feet below the ground surface. An outer "slip" casing of 4-inch diameter pipe was placed around each benchmark to a depth of 10 feet below the ground surface, with the annular space between the outer "slip" casing and the benchmark filled with heavy grease. The principle of

these "non-heaving" benchmarks lies in the outer protective casing, which in every case extended into permafrost, and heavy grease between the pipes to eliminate transfer of frost heave thrust to the inner benchmark pipe.

After 10 years of continuous vertical movement observations (See Figures 5 and 6), there has been a seeming net downward movement of four of these five benchmarks. A 2-inch pipe casing (Benchmark "casing" near RN-13) embedded 156 feet into permafrost was used as a reference; however, the pipe was slurried in without an outer casing and thus was not isolated from frost action thrust in the active zone, up to 1956. Thus the possibility of very slow upward creep of the reference benchmark must be considered a possibility, particularly since there is no apparent physical reason why the other benchmarks should experience any movement.

In 1956, a casing was placed around the reference benchmark and observations in subsequent years should show whether or not this benchmark actually did heave.

Greatest variation in readings is shown for Benchmark "C", which is some distance up a hill from the reference benchmark and therefore involved more set-ups and turning points in each leveling circuit.

4. Other Benchmark Installations in Alaska

Several other benchmark installations have been made throughout Alaska, but no check has been made on the stability.

a. Ladd Air Force Base, Alaska. A steel section of railroad track has been driven and is used as a benchmark. It extends to an unknown depth below ground surface, and it is not known whether it lies in permafrost or entirely in thawed soils as the area is considered marginal permafrost.

b. Kotzebue Air Force Station, Alaska. A benchmark, almost identical with those in operation at the Fairbanks Permafrost Research Area, was constructed at this site in the fall of 1955. There is no way to check the performance of this benchmark except in retrospect because of absence of other known "non-heaving" benchmarks. The benchmark is being used to provide a reference for vertical movement observation of the pile foundation at the station. Since the normal observational errors are the only peculiarity in the movement records to date, it could be assumed that the benchmark is stable.

c. Bethel Air Force Station, Alaska. Two benchmarks were placed at this station in the spring of 1956. They are not of the standard design used by the Fairbanks Permafrost Research Area as both benchmarks are embedded only two feet or less in permafrost. The benchmarks have been used less than one year and the vertical movement records are only now under study so that no comment may be made as to the stability.

5. Recommendations.

a. Permanent and Semi-permanent Benchmarks. Permanent and semi-permanent benchmarks are considered relatively stable for

periods of time in excess of 10 years. Mechanical drilling equipment is required for installation of this type benchmark. The following interim basic design is recommended for permanent benchmarks at sites with a relatively deep active zone. A standard weight pipe with a minimum 2-inch nominal diameter should be placed to a minimum depth into permafrost equal to twice the length passing through the active zone and the residual thaw zone (see Figure 7). The benchmark pipe should have surface irregularities to provide adfreeze bond with the permafrost and to hold the pipe rigid. In the past (Figure 3), 1/4-inch x 12-inch slots have been cut in the pipe, but present recommendations are that a pipe floor flange be attached to the end of the benchmark pipe prior to placement. An outer casing should be provided over the full length of the benchmark in the active and residual thaw zone. This outer pipe should also be embedded into the permafrost so that this will not heave an undue amount during the life of the benchmark. (It is not necessary that this heave be entirely restrained.) A small flange is desirable at bottom of this casing if hole clearance permits. If the outer casing should heave 4 inches a year, for example, it may cause difficulty in use of the inner pipe as a benchmark or may even heave the outer casing 100 percent into the active zone. The critical point in this recommended method is that an Amber Tervan wax - Mentor oil mixture* (or other viscous

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* Amber Tervan Wax and Mentor Oil is manufactured by Esso Standard Oil Company, Everett, Massachusetts.

substitute) backfill placed between the inner and outer pipes must extend 100 percent along the outer casing to prevent the possibility of a plug of soil being in contact between the inner and outer pipes which soil would act to transmit drag from the outer casing to the inner pipe benchmark.

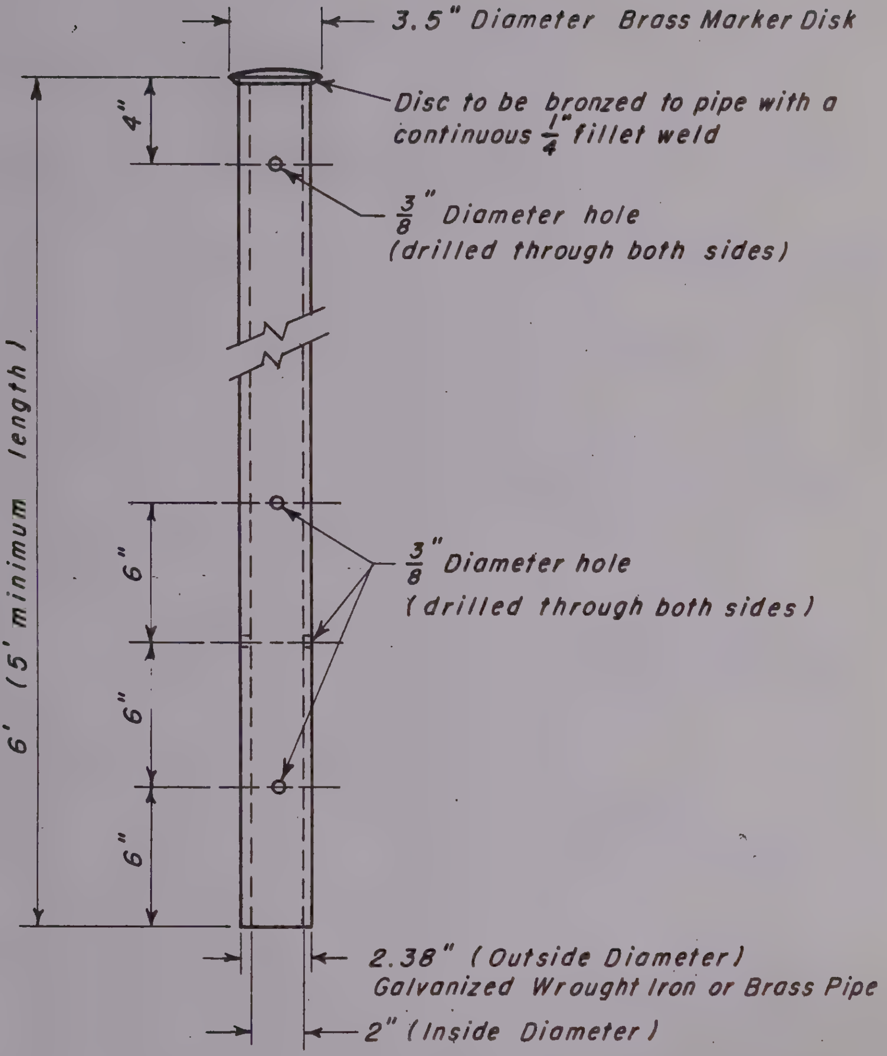
b. Temporary Benchmarks. A temporary benchmark is considered to be relatively stable for short periods of time. The recommended basic principle of design is similar to that of the permanent benchmark, except that the inner benchmark pipe should be placed in a hand augered hole or test pit extended as deep as is feasible by hand methods into permafrost. Installation should be performed in the late summer when thawing has progressed to nearly the maximum depth. An alternate scheme is to hand auger a large hole for the outside casing and drive drill rod for the inner benchmark element. (A small pilot hole may be augered to facilitate driving). The temporary aspect of the benchmark is the inability to advance the inner section deep enough into permafrost to insure rigidity. Nevertheless, the outer casing must be placed and filled with a viscous solution. This procedure is very critical and will definitely determine the stability of the benchmark.

In permafrost areas where transportation facilities are good and there is need for a lasting stable benchmark, it is recommended that a permanent benchmark as described above be installed.

The benchmark design is conservative and there is little question of its stability anywhere in Alaska that permafrost exists and is relatively near the ground surface. Its performance and reliability would be well worth the care and effort expended in its installation.

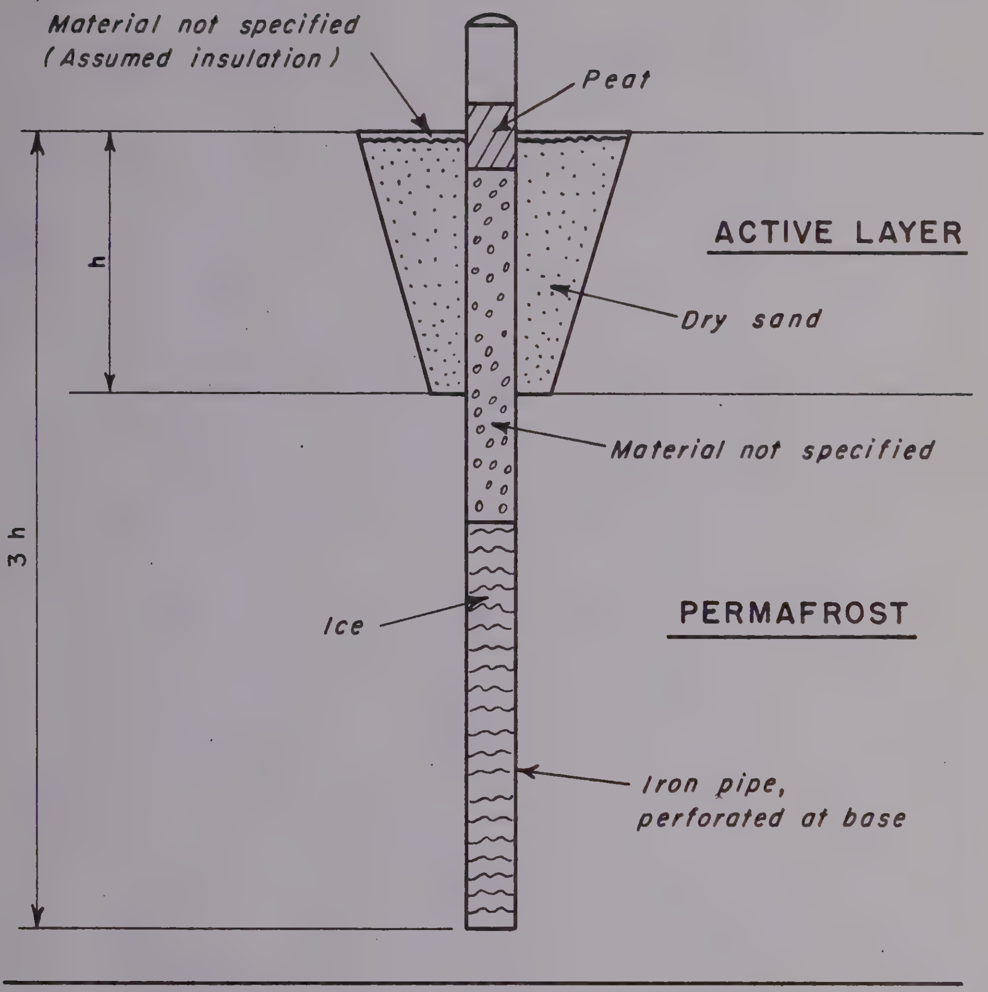
In remote permafrost areas, frequently a heavy drill rig may not be available for installation of the benchmark and equipment may even be restricted to back-packed items. Under such conditions, it becomes vitally important to know what are the minimum depth dimensions and what are the minimum size and weight of pipe which will give a satisfactory installation. At present, however, these considerations are undergoing study and not much is yet known. Therefore, it can only be recommended that benchmarks as described in (b) above be installed. As strict adherence to permanent benchmark installation as possible will determine the stability of the benchmark. If at all possible, hand augered holes are preferred over driving the inner pipe. In driving, it is never possible to predict the depth which can be reached, particularly in arctic permafrost. Where marginal permafrost exists, it may not be known whether or not the inner pipe is all the way through the thawed zone and the benchmark may be of no value.

6. Summary. A good stable benchmark must be solidly anchored in permafrost and must be protected from all seasonal heave forces originating from the active zone by an outer casing filled with a viscous substance which will transmit none of these forces to the benchmark.


3.5" Diameter Brass Marker Disk
Disc to be bronzed to pipe with a continuous $\frac{1}{4}$" fillet weld
4"
$\frac{3}{8}$" Diameter hole (drilled through both sides)
6' (5' minimum length)
6"
6"
6"
$\frac{3}{8}$" Diameter hole (drilled through both sides)
2.38" (Outside Diameter) Galvanized Wrought Iron or Brass Pipe
2" (Inside Diameter)

SPECIFICATIONS
FOR
USCGS SURVEY MARKERS

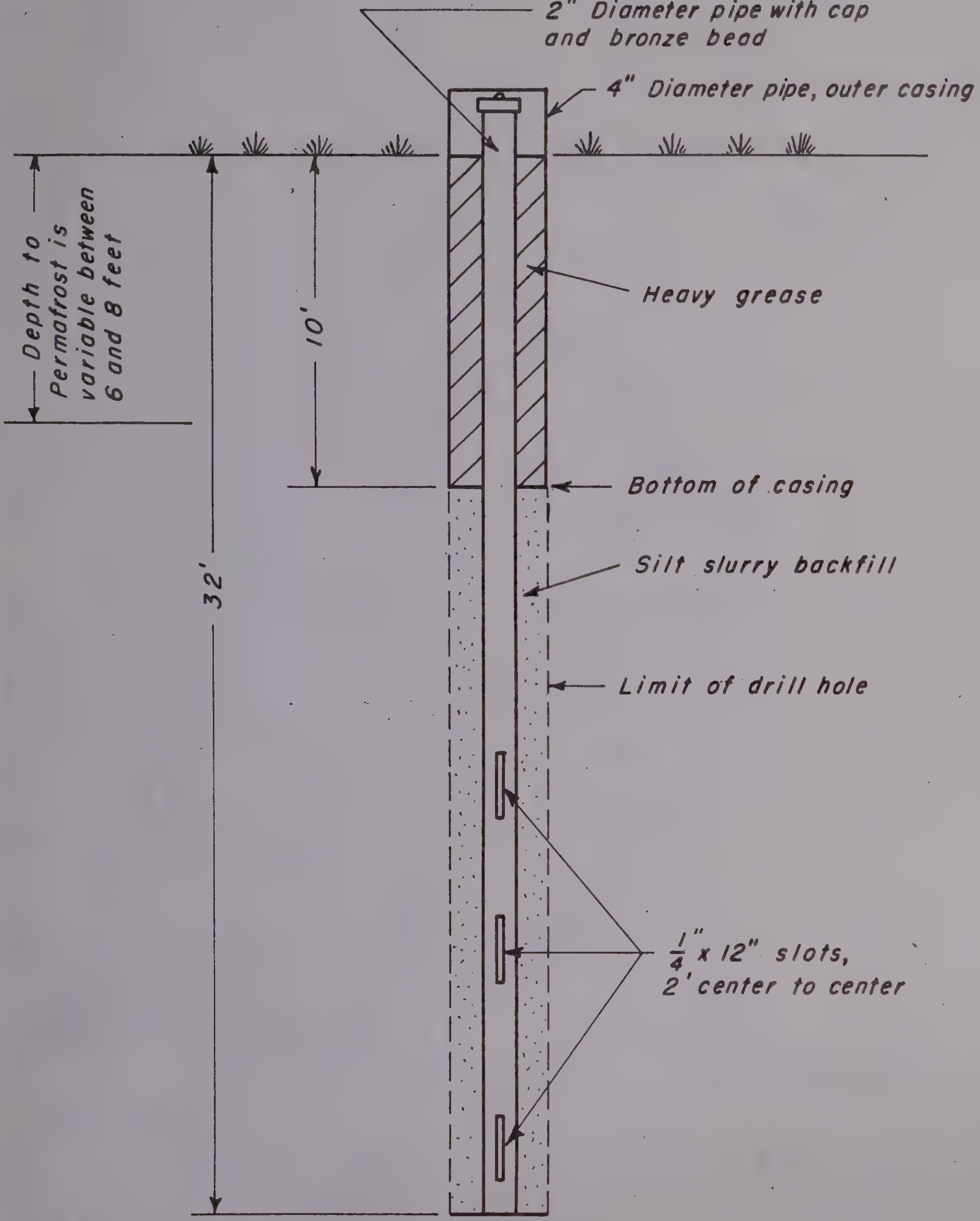
FIGURE 1



RUSSIAN TYPE BENCH MARK

After Bykov and Kopterev

FIGURE 2


2" Diameter pipe with cap and bronze bead
4" Diameter pipe, outer casing
Depth to Permafrost is variable between 6 and 8 feet
10'
32'
Heavy grease
Bottom of casing
Silt slurry backfill
Limit of drill hole
$\frac{1}{4}$" x 12" slots, 2' center to center

TYPICAL NON-HEAVING BENCH MARK, FPRA

FIGURE 3

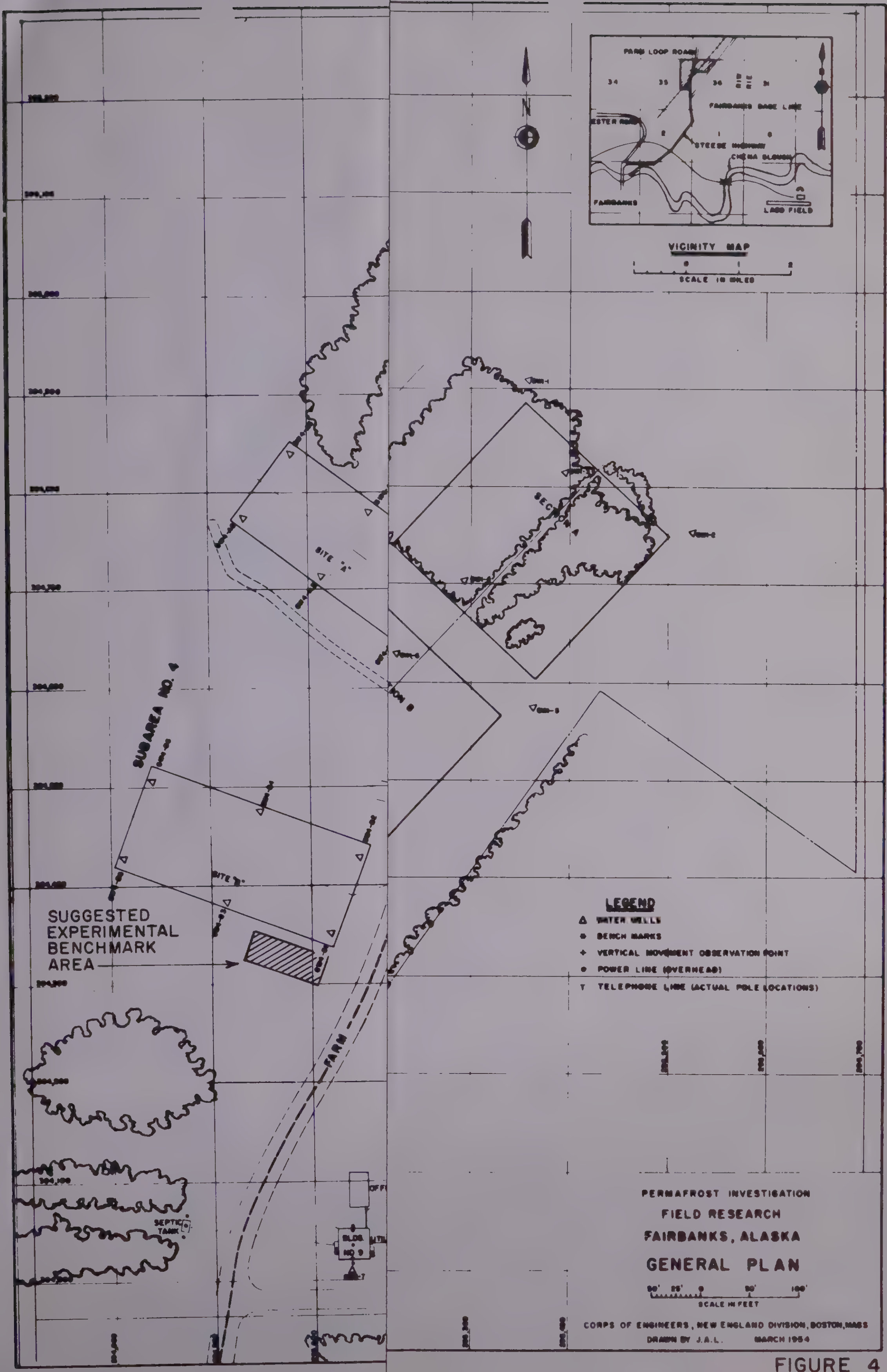
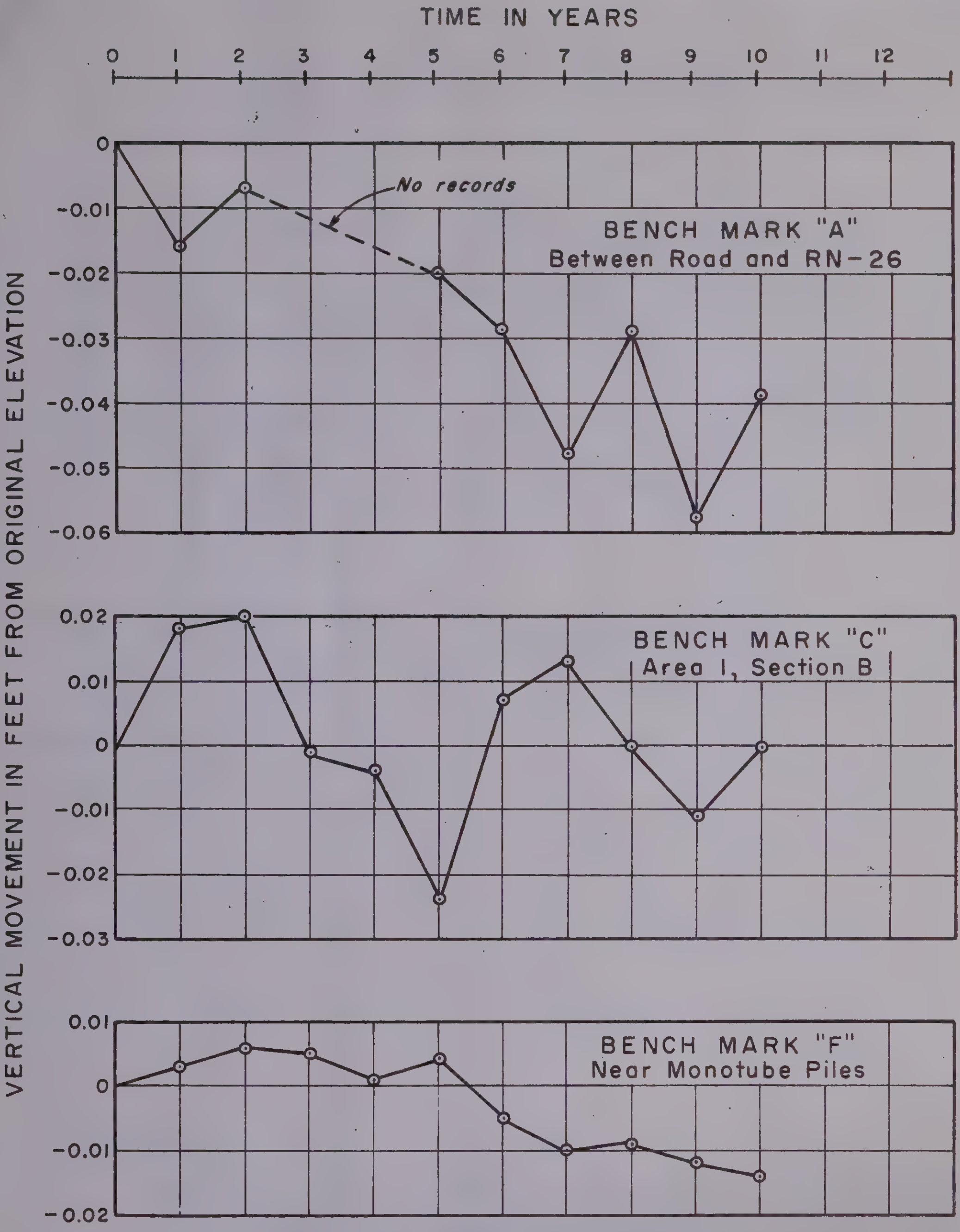

PARK LOOP ROAD
34
35
36
31
FAIRBANKS BASE LINE
ESTER ROAD
2
1
6
STEESE HIGHWAY
CHENA SLOUGH
FAIRBANKS
LADD FIELD
VICINITY MAP
1
0
1
2
SCALE IN MILES
N
SITE "A"
SITE "B"
SECTION A
SUBAREA NO. 4
FARM
OFFI
BLDG. NO. 9
SEPTIC TANK
SUGGESTED EXPERIMENTAL BENCHMARK AREA
LEGEND
△ WATER WELLS
● BENCH MARKS
+ VERTICAL MOVEMENT OBSERVATION POINT
● POWER LINE (OVERHEAD)
T TELEPHONE LINE (ACTUAL POLE LOCATIONS)
PERMAFROST INVESTIGATION
FIELD RESEARCH
FAIRBANKS, ALASKA
GENERAL PLAN
50'
25'
0
50'
100'
SCALE IN FEET
CORPS OF ENGINEERS, NEW ENGLAND DIVISION, BOSTON, MASS
DRAWN BY J.A.L.
MARCH 1954

FIGURE 4



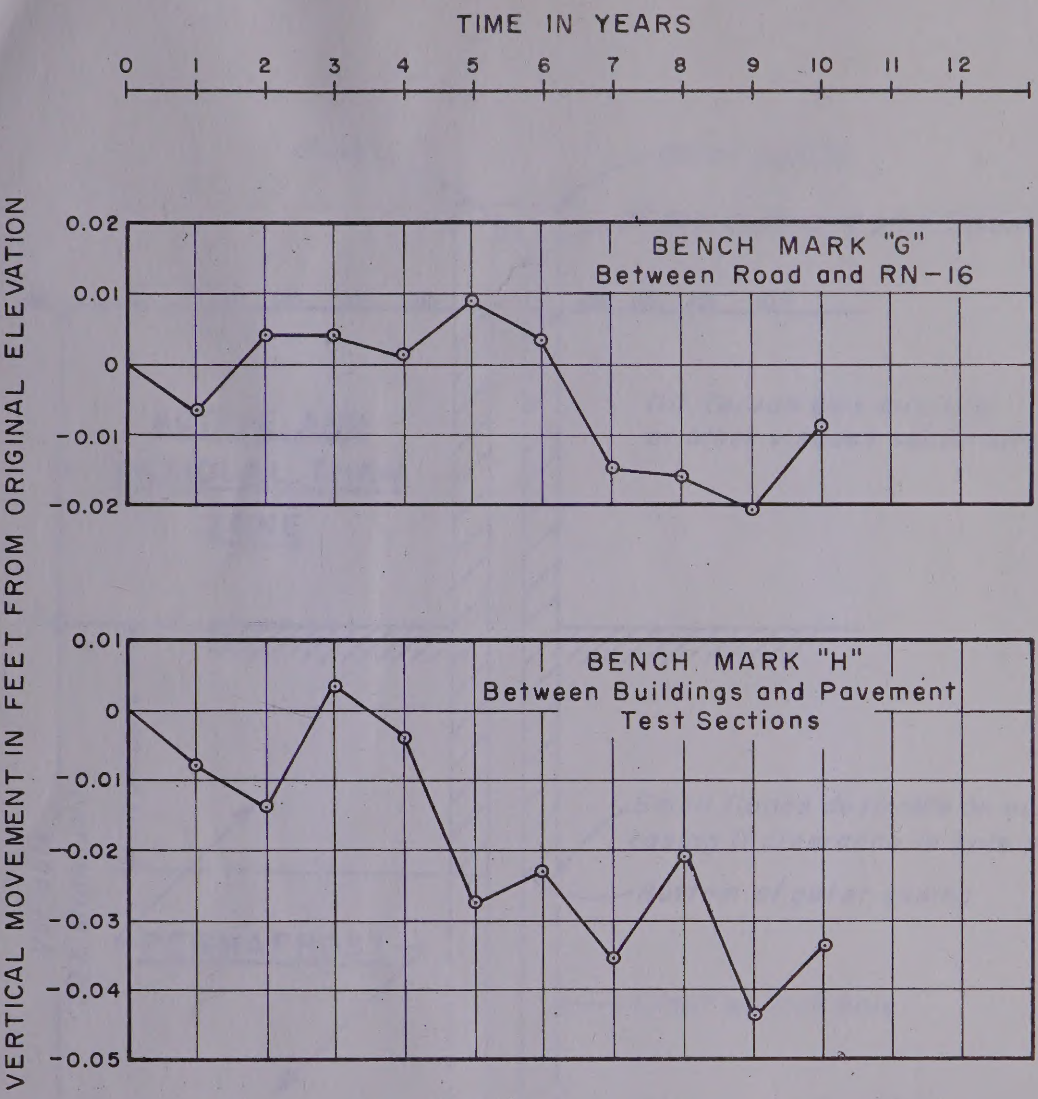
NOTES:

Elevations are in reference to Bench Mark Casing near RN-13.

All points represents elevation difference as recorded in late february or early March of each year following initial observations.

VERTICAL MOVEMENT OF BENCH MARKS
FAIRBANKS PERMAFROST RESEARCH AREA

FIGURE 5



NOTES:

Elevations are in reference to Bench Mark Casing near RN-13.

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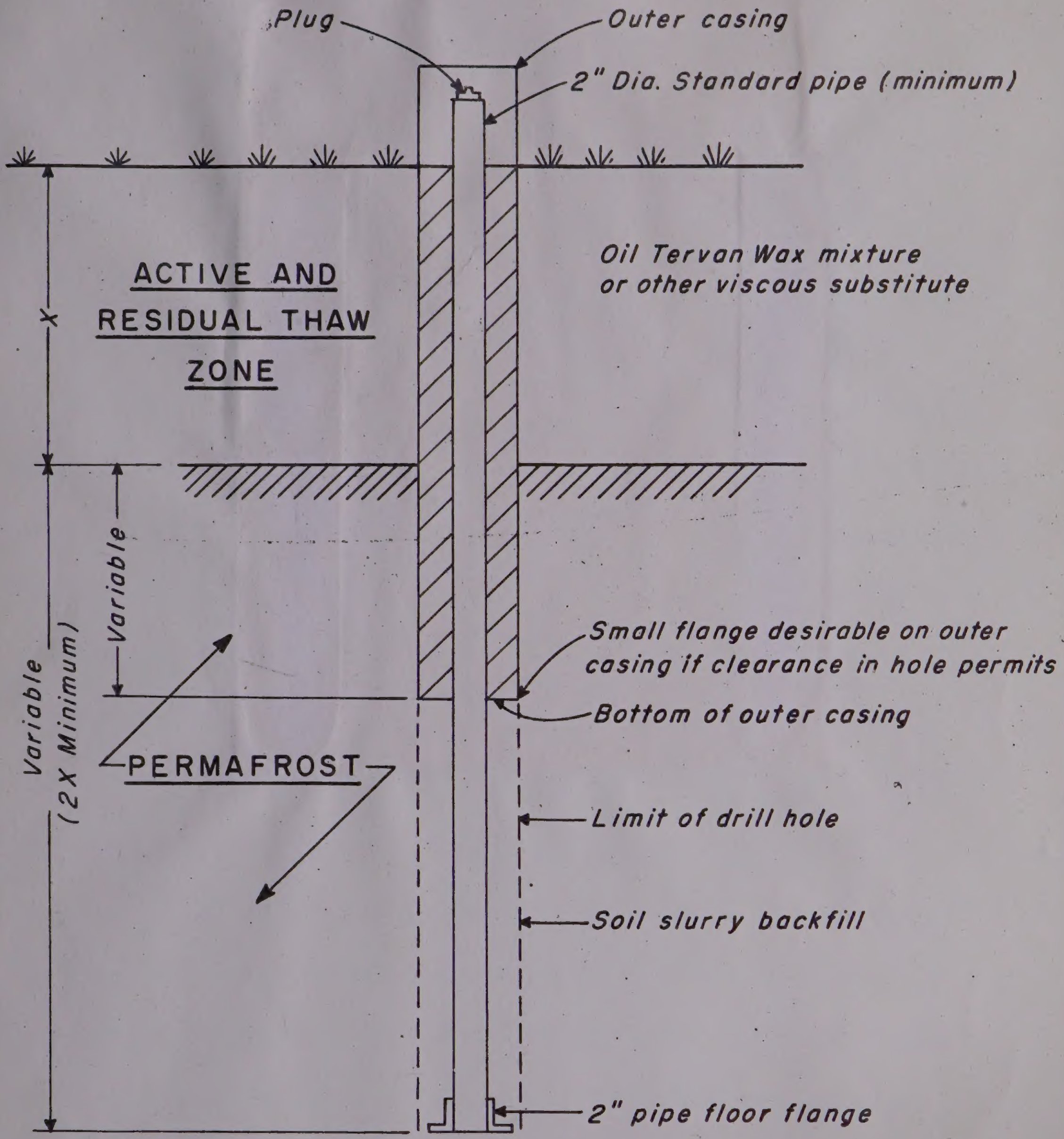
VERTICAL MOVEMENT OF BENCH MARKS

FAIRBANKS PERMAFROST RESEARCH AREA

FIGURE 6


Plug
Outer casing
2" Dia. Standard pipe (minimum)
ACTIVE AND RESIDUAL THAW ZONE
X
Oil Tervan Wax mixture or other viscous substitute
Variable
Variable (2X Minimum)
Small flange desirable on outer casing if clearance in hole permits
Bottom of outer casing
PERMAFROST
Limit of drill hole
Soil slurry backfill
2" pipe floor flange

RECOMMENDED PERMANENT BENCH MARK, ACFEL

FIGURE 7

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Army-Corps?
Engineers.

arkell in
-Grained

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